NOTES ON DIPTEROCARPS.

No. 4. On the Embryo, Seedling and Position of the Flowers in various Species.

By I. H. Burkill.

This note deals, with the shape of the mature embryo, and with the characters of the seedling in a small number of species of the order Dipterocarpaceae: it deals also in a lesser measure with the position which the flowers assume when open. The observations were made and are recorded because it is believed that by a full knowledge of the morphology of the young plant, light will be cast upon the tangle which the genera of the order now present. In a lesser measure the position of the flower may possibly assist; and at any rate information concerning it is worth collecting.

Most of the facts in this note were got together by visits to Penang in the months of July, October and December, 1918: such as were not, are enumerated in the footnote* below. It happened that the year, 1918, was unusually favourable to the Dipterocarps in Penang, where almost every local species flowered: and there Mr. Mohamed Haniff, of the Waterfall Gardens, observed and collected for me between my visits. To him for very much assistance, I tender my best thanks. I tender my best thanks, also, to Dr. F. W. Foxworthy, Mr. W. E. Kinsey and other Forest Officers for supplies of fresh seed from several parts of the Peninsula, which seed was put into cultivation in the Botanic Gardens, Singapore. No cultivation, however, returned the equivalent of days spent in the forests when the seeds were falling and germinating under natural conditions; for the seedling is so exacting in its demands that without experimenting on a very large scale cultivation often fails to supply adequate material.

The forest is undoubtedly the place in which to study the Dipterocarps. The earlier investigators were not able to realise that fully, not even collectively, and have left much to be done. The first of the workers worked, perforce, in European institutions remote from tropical nature, with material preserved by drying and chiefly collected by others. They constructed such classifi-

* The following list gives the names of the plants which were not studied in Penang, but in Singapore:

Shorea gratissima Dyer, *S. leprosula* Miq. *Balanocarpus Zeilanjbus* Thw., and *Pachynocarpus Wallichii*, King species wild or long established in the Botanic Gardens, Singapore. *Hopea Mengarawan*, Miq., wild in Singapore, island. *Dipterocarpus cornutus*, and Dyer, *Hopea Curtisii*, King, seeds grown from Penang *Dipterocarpus crinitus*, Dyer, *D. grandiflorus*, Blanco, *D. Kerrii*, King and *Dryobalanops aromatica*, Gaertn.f., seeds grown from Negri Sembilan,

Dipterocarpus Scorteohinii, King, and *D. ep.* seeds grown from Selangor.,

cations as they could with what they had. Bentham for instance in Bentham and Hooker's *Genera Plantarum,* i, (1862) p. 190, after saying that the calyx in fruit gives the best key, presented an alternative on the structure of the flower: and Alphonse de Candolle in his *Prodromus,* xvi, part 2, (1868) p. 604 took a different line in classifying by the number of stamens. Heim, much later (*Recherches sur les Dipterocarpacées, Introduction à la Monographie générale de la Famille,* Paris, 1892, p. 14), when essaying to throw light upon the order by means of the microscopic structure, wrote " the shape of the embryo is very variable, according to the genera,—and this shape, wrongly neglected by writers, may furnish generic characters of the highest importance:" But Brandis in the *Journal of the Linnean Society, Botany,* xxxi, 1895, p. 15, refused to allow importance to it, stating that the variability is great even among species otherwise closely allied. I am with Heim in thinking that there is a promise of utility in the study of the embryo.

Brandis' effort is the last that has been made at classifying comprehensively the Dipterocarps of the World. He had long been an Indian Forest Officer: but he did it as herbarium work, his field knowledge of the order remaining limited to the relatively small number of species found in India. Few will regard the result as satisfying our need.

Upon the botanists who live where Dipterocarps grow, now rests the duty of collecting such details regarding them as the Herbarium botanists have not had in full measure, and among the details, as Heim has pointed out, are the structure of the embryo and appearance of the seedling. Trimen, indeed, made some observations on the structure of the embryo of the Ceylon Dipterocarps (*Handbook of the Flora of Ceylon,* i, 1893, pp. 112-138 and his plates 13-15), but not comparatively between the species; and Pierre in his beautiful *Flore Forestière de la Cochin-Chine,* Paris, 1888, plates 212-259, figured many embryos, but unfortunately nearly always in a slightly immature state. I find consequently in his plates indications rather than facts, and trust that some day soon there may appear a botanist in Indo-China who will delineate the seedlings and mature embryos of the Dipterocarps which make so large a part of the forests there.

Six ovules occupy in pairs the three chambers of the ovary of any one of the Dipterocarps. Out of the six except in cases which are rare, and of which a few have been recorded, one only develops into a seed. Brandis who in 1895 drew together the observations of earlier writers on the order, was able to cite but three species in which twin seeds had been found, namely *Dipterocarpus condorensis,* Pierre, *Dipterocarpus alatus,* Roxb., and *Dryobalanops aromatica,* Gaertn. f. (Engler's *Pflanzenfamilien,* iii, part 6, p. 251). To these Mr. B. Sen-Gupta (*Indian Forester,* xliv, 1918, p. 372) adds *Shorea robusta,* Roxb., with the remark that twin seeds are not infrequent.

I have now to add several more; and it seems as if any few thousand seeds of a species may be expected to give an instance or two. The species which I have to add are:—*Dipterocarpus cornutus,* Dyer, *Dipterocarpus alatus* of Penang (? Roxb.), *Anisoptera Curtisii,* King, *Shorea macroptera,* Dyer, *Shorea pauciflora,* Dyer, *Shorea gratissima,* Dyer, *Shorea parvifolia,* Dyer, *Retinodendron pallidum,* King, and *Pachynocarpus Wallichii,* King.

When two seeds are formed in the limited space of the one ovary, they interfere with each other in a way which will be described.

The single normal seed is produced with its radicle towards the apex of the ovary cavity, and with one cotyledon against the placenta. The placenta with the sterile loculi behind it persists, in most genera distinctly, as a chord to the curve of the ovary wall, while the embryo in growth laps round it. Thus the placentar cotyledon becomes doubled on itself backward over the placenta, and acquires a groove which, because the placenta remains firmly attached to the middle of the base of the ovary, in most genera leads to the embryo appearing with a seam down one side ending in an umbilicus. The other cotyledon becomes doubled ventrally onto the placentar cotyledon, and may shut the placentar cotyledon from the apex of the fruit-chamber. The embryo consequently acquires an obliquity which varies in the different species studied, and will be described with figures to indicate its degree.

But occasionally the embryo comes through its development without folding itself over the placenta. Instances have been found in the genera *Dipterocarpus, Shorea* and *Retinodendron,* which will be described. In them there is some indication of a spiral growth which throws the cotyledons into an S. The causes of it have not been ascertained; but *Dipterocarpus* where the placenta is least in evidence in the mature fruit, is the genus yielding instances most readily.

Dipterocarpus.

The flower of *Dipterocarpus* usually, it seems, faces earthwards; and after flowering is done, the growing fruit maintains the position: it is as in figures 1 and 2.

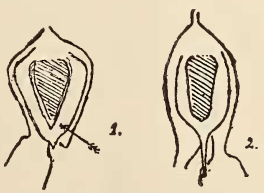


Figure 1. fruit of *Dipterocarpus alatus,* and figure 2, fruit of *D. fagineus*; both in vertical section with the embryo shaded. The arrow on figure 1, indicates the position at which a very common weevil emerges when its grub has completed the devouring of the seed and has passed through a period of pupation.

When the fruit is ripe it falls as a shuttle-cock to the floor of the forest and there without delay germinates. The embryo, at fruit-fall, and if normal, is as in figures 3 and 4, the placentar cotyledon being enwrapped more or less completely by the other, the radicle extruding slightly from the basal lobes that the cotyledons possess, or just covered by them.

Figures 3, an embryo of *Dipterocarpus cornutus* from the placentar side and 4, from the back. In figure 3 the edges of both the cotyledons are seen; in figure 4 a fold is seen in the upper part of the outer cotyledon. Nat. size.

The way in which the placentar cotyledon in enwrapped, will be adequately realised from the series of sections, figures 5 to

Section of embryo of *Dipterocarpus cornutus* near the a pices of the cotyledons. The placentar cotyledon only comes to the surface at this level at the side which is above in the figure.

Section lower. The placentar cotyledon just comes to the surface.

Section lower. The placentar cotyledon is quite enclosed.

Section lower, with the same appearance. The bundles of the petioles of the cotyledons have not spread into the blades at this level.

Section lower, at the junction the petiole of the placentar cotyledon with its blade.

Neighbouring section to the last, the petiole free.

Section through the petioles and plumule with the lobes of the cotyledon round them, those of the placentar cotyledon enclosed.

Section lower, one lobe of the placentar cotyledon reaching the surface.

Section through radicle with the lobes of the cotyledons round it, one quite enclosed.

13, but they represent an extreme; for it is not usual for the placentar cotyledon to be so fully enveloped by the other. Figure 14 is of a commoner condition. In it the placentar cotyledon (at the level of the section, which is at one third from the apices of the cotyledons) comes to the surface over about one fifth of the circumference. Figure 15, which is of a different species, shows it on the surface over one-third of the circumference.

Figure 14, section of the embryo of *Dipterocarpus cornutus* showing the placentar cotyledon at the surface over one-fifth of the circumference, and the outer cotyledon with three folds at the back; figure 15, section of the embryo of *Dipterocarpus alatus*, of Penang with the placentar cotyledon at the surface over one-third of the circumference.

Figures 16, 17 and 18 represent sections through the embryo of a new *Dipterocarpus* from Selangor, with rather small fruits. The placentar cotyledon is folded inside as described above. But figures 19, 20 and 21 show in the same species, the different folding mentioned above as resulting in the cotyledons being curved into an S., where neither is inside the other.

S.-folding was observed in *Dipterocarpus fagineus,* Vesque, *D. alatus* of Penang, *D. cornutus,* Dyer, and this new species.

Figures 16—21, section through two embryos of *Dipterocarpus,* n.sp.

Figs. 19—21, showing on the right the usual folding, Figs. 16–18, on the left a folding into the letter S.

The embryo of *Dipterocarpus fagineus* was found folded as in figures 22, 23, 24, 25, 26, and 27, and the embryo of *Dipterocarpus cornutus* as in figures 28, 29 and 30, a very similar arrangement to that seen in figures 19, 20 and 21.

Figures 22-27, sections through an embryo of *Dipterocarpus fagineus*;

Figures 28-30, ditto, through an embyo of *Dipterocarpus cornutus*.

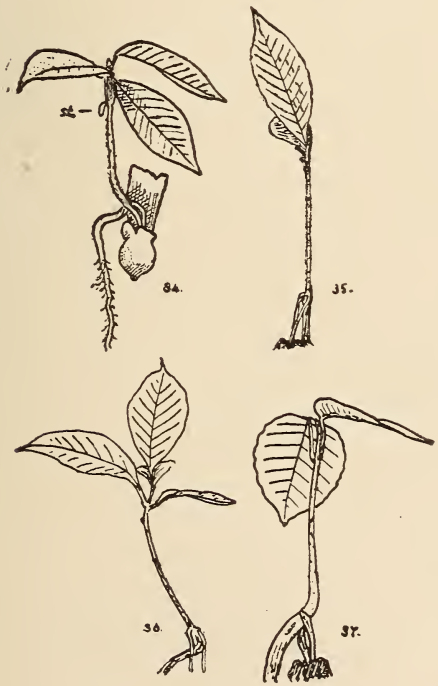
It seems worthy of notice that in the folding of the cotyledons in the largest fruited of these three an extra curve is called into being (figure 28) indicated only just in the smaller embryo of *Dipterocarpus fagineus* (figure 22).

Twin seeds in *Dipterocarpus cornutus* exhibited an S-folding. Did it result from the intensified and abnormal pressure from competition within the ovary? It became complicated by extra folds.

Figures 31, 32, and 33, sections through twin seeds in *Dipterocarpus cornutus* in three levels.

The apices of the cotyledons in the genus *Dipterocarpus* not uncommonly abut against an small lump of resin which acts as ballast when the fruits fall.

After reaching the ground the radicle is extruded from the apex of the fruit without any well defined cracks spreading down the fruit wall; it is thrust out by the elongation of the petioles of the cotyledons as figures 34, 35, 36 and 37 indicate, and growing, exhausts the cotyledons of the nutriment stored in them, without the development in them of any visible change. They do not part in any way nor develop chlorophyll. Why has the genus *Dipterocarpus* thin cotyledons, so much broader and more leaf-like than is usual in the order, without any function attached that belongs to the thinness of leaves? Their elaborate folding is a consequence of their size. Their surfaces which are morphologically upper surfaces are very uneven. Why? They fit so tightly together, that slipping over each other would seem impossible; but the morphologically lower surfaces are smooth, as the drawings indicate, and obviously one part slides over another in growth.



Figures 34-37, Seedlings of:—
(34) *Dipterocarpus Scortechinii*
(35) *D. crinitus*.
(36) *D. Kerrii*. and
(37) *D. grandiflorus*
All about nat ½size.

Dipterocarpus produces after the cotyledons first a pair, and then alternating leaves, the first of the alternating leaves is not crowded onto the pair, at any rate not in *D. Scortechinii*, King, *D. fagineus*, Vesque, *D. cornutus*, Dyer, *D. grandiflorus*, Blanco, *D. alatus* of Penang, *D. crinitus*, Dyer, nor *D. Kerrii*, King.

Dryobalanops.

The great disparity between the two cotyledons of *Dryobalanops aromatica* has been known for over a century; a tree of such economic importance naturally attracted the attention of early voyagers in the Malay region, and Gaertner about a century and a quarter ago was able to examine its seeds, and to figure them in his *De fructibus*, 1788-91. Then again Correa de Serra in the *Mémoires du Muséum d'Histoire Naturelle*, i, 1815, p. 159 and Colebrooke in the *Asiatick Researches*, iii, 1816, figured it; later others. But apparently the actual germination has not been described, though the dehiscence of the fruit has been recorded as along three defined lines, and abundantly commented on.

Figure 38 is of the young seedling seen from the side, and figure 39 of its cotyledons seen from above. The larger of these cotyledons is slightly cup-shaped when expanded, the other slightly humped; and they come to stand horizontally. Their upper surface is as rough as that of a *Dipterocarpus*, but their cells are full of chlorophyll.

Figures 38 and 39, the seedling of *Dryobalanops aromatica* from the side and from above, showing how the cotyledons expand, how unequal they are, and how uneven is their surface; nat size.

Figure 40 is a section down the germinating fruit showing the radicle extruding and curving earthwards. It shows also the extraordinary invagination of the placenta, of which the genesis is unstudied, and the function if any, quite obscure. This invagination is like an apron in shape; round its edges at either side curves the dorsal cotyledon embracing with it the inner or placentar cotyledon.

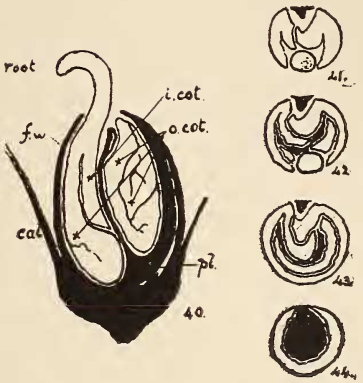


Figure 42, the germinating fruit of *Dryobalanops aromatica* in vertica-median section, showing cal. = a calyx lobe: f. w. = fruit wall: pl. = plal centa: i. cot. inner or placentar cotyledon: o. cot. = outer cotylepon, cut in three places. Nat. size. Figures 41, 42, 43 and 44, sections through the embrio at various levels showing how the outer cotyledon enwraps the placenta coty-ledon and the process of the placenta.

The embryo soon frees itself from the fruit wall and seed-coats, uncurling as in figure 45.

Figure 45, the seedling of *Dryobalanops aromatica* showing the outer cotyledon half expanded, ½ nat. size.

The lesser or placentar cotyledon becomes as horizontal as the larger, and a rather long wiry stem grows upward bearing first a pair of leaves and then, closely approximated to this pair, another pair before alternate leaves succeed, as shown in figure 46. If the reader will turn back to figures 34-37, he will at once see how dis-similar is this plantlet to the seedlings examined of the genus *Dipterocarpus*.

Figure 46, a seedling of *Dryobalanops aromatica* with it first few leaves, ⅓ nat. size.

HOPEA, section DRYOBALANOIDES.

Figure 47 is the fruit of the *Hopea* common on Penang island, which will be called here *Hopea micrantha,* Hook. f.; and figure 48 is its embryo seen with the radicle away from the observer. Figure 49 is of the wiry seedling which arises from it, and figures 50, 51, 52 and 53 are of its two cotyledons from both sides.

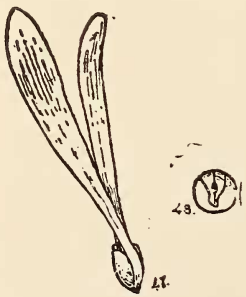


Figure 47, a fruit of *Hopea micrantha,* nat. size; and figure 48, its embryo seen with the radicle away from the observer.

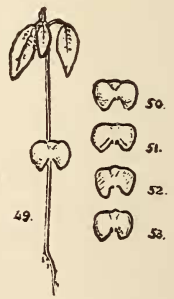


Figure 49, the wiry seedling of *Hopea micrantha ;* figure 50 the outter cotyledon from the outside, figure 51, from the inside ; figure 52, the placentar cotyledon from the side in contact with the outer cotyledon; fig. 53, from the placentar side ; ½ nat. size.

As figure 49 shows, the seedling bears a pair of leaves, followed by closely approximated alternate leaves, much after the manner of *Dryobalanops aromatica,* only that they are distinctly alternate. In its wiriness it is also similar.

The seedling develops a small amount of red pigment.

Hopea mengarawan, Miq. from Singapore island, but little distinct from the last, is represented in figure 54, and a section through its embryo in figure 55. This section shows that the cotyledons are rather thin and that the outer goes far towards enveloping the inner. The name " H. mengarawan " is used as Mr. Ridley has used it: Miquel's type has not been compared.

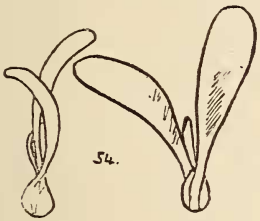


Figure 54, a fruit of *Hopea mengarawan.* ½ nat. size.

Figure 55, the embryo of *Hopea mengarawan* in section.

The reader will observe that the similarity of the Hopeas of the section *Dryobalanoides* to the genus *Dryobalanops* as seen in the mature foliage, is repeated in certain characters of the seedling.

Balanocarpus (excluding Richetia).

Balanocarpus Curtisii, King, will be described next. It is a common small tree of some parts of Penang island.

As in the genus *Dipterocarpus,* the flowers face earthwards; but they are small, and illustrate the statement that greater size and downward direction in anthesis do not accompany each other through the order. They are claret in colour, with petals but little twisted.

Figure 56, a flower of *Balanocarpus Curtisii* in vertical section, × 4.

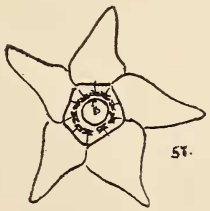


Figure 57, a flower seen from below, × 4.

Figure 58, a young fruit in vertical section, × 4.

From the nearly globose fruit a wiry seedling arises, with a pair of leaves and with alternate leaves following them approximat-

ed to the pair, the first of the approximated alternate leaves being almost in a false whorl with the pair.

The cotyledons are very like those of *Hopea micrantha*,—rather thin and nearly vertical in position; but the margin of the outer has a rather characteristic rim surrounding plano-convex areas. Red pigment is present in them and in the leaves which follow them.

Figure 59, the seedling of *Balanocarpus Curtisii*, showing the approximation of the third (3) and fourth (4) leaves to the paired leaves, ½ nat. size.

Figure 60, the outer cotyledon of *Balanocarpus Curtisii* seen from the outside; figure 61, from the inside. figure 62, the placentar cotyledon seen from the side against the outer cotyledon, figure 63, from the other side nat., size; figures 64 and 65, the position taken by the cotyledons with regard to each other.

Balanocarpus zeylanicus, Trim., a species cultivated in the Botanic Gardens, Singapore, has flowers directed earthwards, from ascending branchlets as in figure 66. The flowers are as in figures 67 and 68, with the petals distinctly twisted. The seedling produced is as in figure 69, its cotyledons as in figures 70 and 71. In section the embryo is as in figures 72, 73 and 74.

Figure 66, a branch of *Balanocarpus zeylanicus* showing the ascending branchlets, ¼ nat. size; figure 67, the flower in vertical section, × 2; figure 68 the flower in face view, × 2.

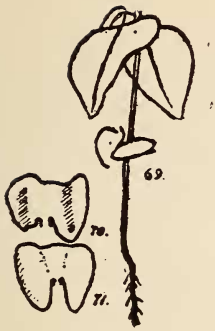
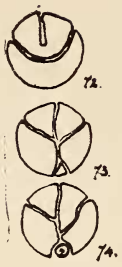


Figure 69, the seedling of *Balanocarpus zeylanicus*, ½ nat. size; figure 70, its placentar cotyldon seen from the side away from the outer cotyledon: figure 71, the outer cotyledon seen from the outside, nat. size.



Figures 72, section of the embryo through the upper part of the cotyledons; figure 73, section through the plumule; and figure 74, section through the radicle.

Trimen (*Handbook to the Flora of Ceylon*, i, 1893, p. 130), doubted if he had classified it rightly as a *Balanocarpus*.

Vatica.

With *Vatica nitens* another type of Dipterocarp embryo is reached. In it the placentar cotyledon is rolled rather then folded, and the outer cotyledon embraces it (vide figure 75). The placentar cotyledon is horned as figures 76, 79 and 80 show. The revolution of the placentar cotyledon suggests *Dipterocarpus*.

Figure 75, the embryo of *Vatica nitens* with the radicle away from the observer.

Figure 76, the young seedling of *Vatica nitens* with the placentar cotyledon towards the observer; figure 77, the outer cotyledon from the outside; figure 78, from the inside; figure 79, the placentar cotyledon from the side toward the outer cotyledon and figure 80, from the other side, ½ nat. size.

Red pigment is plentifully present in the cotyledons. Several seedlings of this species were found in which the cotyledons had been bent into an S.

Retinodendron.

The genus *Retinodendron* has been examined in *R. pallidum;* and figure 81 represents a germinating fruit which had been disturbed in the course of its germination so that the direction of the radicle had been changed. That change is of course immaterial to the structure under examination. Figure 82 is an embryo viewed with the radicle away from the observer. The placentar cotyledon is folded rather than revolute. When the seedling develops, the placentar cotyledon is seen to possess one marked horn, and one scarcely defined. So far these horns have been found in *Vatica* and *Retinodendron* alone.

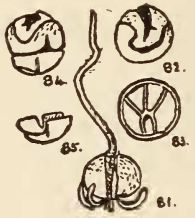


Figure 81, the fruit of *Retinodendron pallidum* germinating; ½ nat. size; fig. 82, the embryo seen with the radicle away from the observer; fig., 83, a section of the embryo through the lobes of the cotyledons and the radicle; figure 84, twin embryos seen with the radicles away from the observer; figure 85, the smaller of these.

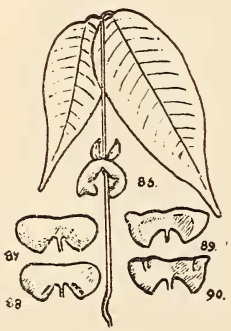


Figure 86, seedling of *Retinodendron pallidum*; figure 87, its outer cotyledon from outside; figure 88, from inside; figure 89, the inner cotyledon from the side towards the outer cotyledon; figure 90, from the other side; all ½ nat. size.

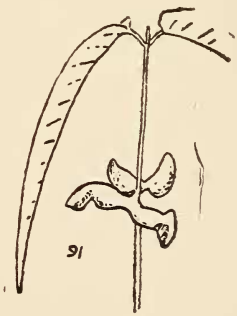


Figure 91, Seedling of *Retinodendron pallidum* showing the ultimate position of the cotyledons: rather more than ½ nat. size.

Figure 92. the outter cotyledon of *Retinodendron pallidum* from outside; figure 93, from inside; figure 94, the placentar cotyledon from the side towards the outer cotyledon; figure 95, from the other side. ½ nat. size.

Retinodendron cotyledons an claret in colour. Figures 84 and 85 present a case of twin seeds. Apparently they arose from the ovules of one loculus for the placentar cotyledon of the seed represented above is turned away from the seed represented below: this cotyledon is folded normally; but under the unusual pressure the outer cotyledon has taken on an S-curvature such as has been recorded for the genus *Dipterocarpus*. The cotyledons of the lesser seed are packed in an X-form each partly above and partly below. The better to show this they have been drawn in figure 85 slightly apart. Figure 96 shows the cotyledons of another abnormal seed wherein there had been a similar packing of the lobes: two such cases were observed.

Figure 96, cotyledons of an abnormal seedling of *Retinodendron pallidum* in which each had been packed partly above and partly below the other, ½ nat. size.

Anisoptera.

The embryo and seedling of *Anisoptera costata* were described in this Journal No. 75, 1917, pp. 43-48. The observations here to be recorded were made upon another species, *A. Curtisii*, King, frequent in Penang island. Figure 97 is its embryo seen with the radicle away from the observer. Figures 98, 99 and 100 are successive stages in its germination. Figure 101 is a seedling with its false whorl of four leaves. These four leaves obviously represent a pair with two others drawn into a whorl with them: the condition is the limit of approximation of the leaves which follow the pair as in *Dryobalanops aromatica* and the Hopeas of the section Dryobalanoides. But so thoroughly have these following leaves been incorporated into a whorl with the pair that they are not recognisable constantly by size and one of them quite commonly exceeds in its length one of the leaves of the pair. To this state I called attention in describing the seedling of *Anisoptera costata*, without then having the key to the origin as given by the examination of the germination of *Dryobalanops* and *Hopea*.

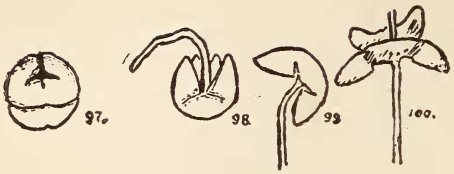


Figure 97, the embryo of *Anisoptera Curtisii* with the radicle away from the observer; figures 98, 99 and 100, successive stages in the germination of this embryo. Nat. size.

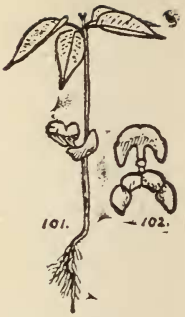


Figure 101, the seedling of *Anisoptera Curtisii* showing its false whorl of four leaves; nat. size; figure 102, the cotyledons obliquely from above.

On seedlings of *Anisoptera Curtisii* I have made the following measurements.

Measurements in millimetres of the lengths of the leaves of the false whorl in seedlings of Anisoptera Curtisii, *the leaves in succession round the axis clockwise.*

Series A. Larger seedlings, where unilateral growth was evident.

81	83	74	74
53	52	50	51
54	55	50	52
63	60	59	60
74	72	63	70
48	56	44	45

Series B. Smaller plants with evident unilateral growth.

31	30	29	27
30	30	29	29
29	30	29	29
34	32	32	32
34	31	26	28

Series C. Where the first pair (the lower line of each pair of lines) was more or less distinguishable from the following leaves.

	79		25
86		85	
	60		61
69		61	
	57		60
64		61	
	61		59
65		64	

{	58		52
{60		60	
{	51		52
{59		55	
{	50		40
{52		50	

In figure 97 the reader well observe that the outer cotyledon does not embrace the placentar cotyledon at all. The genesis of the ridges of the placentar cotyledon will be observed also, the grooves which separate them being creases arising in the curling of the thick cotyledon. The outer cotyledon through life remains the smaller (vide figure 102), and its petiole is about 1 mm. shorter.

Figure 103 and 104, the embryos of two fruits with twin seeds; the placentar cotyledon is the inner in both cases and is not curved. The ovules which gave rise to the seeds were of different loculi.

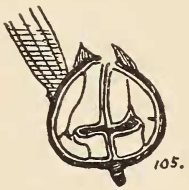


Figure 105, a vertical section through a fruit of *Anisoptera Curtisii* with twin seeds in separate loculi, with the placenta between them and showing its curious process into the seeds, nat. size.

In *Anisoptera Curtisii* I found twin seeds to be frequent; figures 103, 104 and 105 illustrate them. When twins were present they were as far as seen in different loculi. Then the placentar cotyledon would be unfolded as the drawings show. Into it a process of placentar tissue runs, which gelatinises at the maturity of the seed, and seems to be homologous with the apron like process described above as found in *Dryobalanops*.

The seedlings of *Anisoptera costata* and *A. Curtisii* do not develop in their tissues red pigment.

Balanocarpus section Richetia.

Balanocarpus penangianus, King, is a very common tree on the hills of the Island of Penang; and in 1918 it fruited very freely. The fruit is as drawn in figure 106. Its radicle commences to protrude before any distinct cracks spread down the fruit wall. Figure 110 is the embryo, seen with the radicle remote from the observer, and figures 107, 108 and 109 are sections through it at different levels.

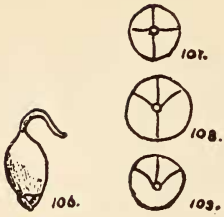


Figure 106, fruit of *Balanocarpus penangianus*, germinating, ½ nat. size; figure 107, section through the embryo showing the radicle central between the equal lobes of the cotyledons; figure 108, section at the middle showing the lobes of the placentar cotyledon at this level rather smaller than those of the outer cotyledon; figure 109, section through the plumule showing the placentar cotyledon here the smaller.

Figure 110, embryo of *Balanocarpus penangianus* seen with the radicle remote from the observer; figures 111, and 112, the cotyledons; in figure 112, the placentar cotyledon is toward the observer, nat. size.

The cotyledons are of a deep red, nearly equal, and stand parallel on short petioles as drawn (figure 111). A pair of bright green leaves follow them having remarkably long acuminations: so long are these acuminations that when the leaf is just expanding they make one-half of its length, and at maturity one-third. The stem is wiry.

No Malayan Dipterocarp has been observed with a more easily recognised seedling than has *Balanocarpus penangianus*.

Hopea, section Euhopea.

Hopea Curtisii, King, has a seedling in many respects like that of some species in the genus *Shorea*. The fruit is globose as figure 113 indicates. The naked embryo seen with the radicle remote from the observer is as in figure 114, or germinating with the placentar cotyledon towards the observer as in figure 115.

Figure 113, A fruit of *Hopea Curtisii*, ½ Nat. size; figure 114, an embryo with the radicle away from the observer, and figure 115, germinating, with the placentar cotyledon, towards the observer, × 1.

The outer cotyledon is considerably larger than the placentar cotyledon and alone reaches the apex of the ovary; figures 117, 118 119 and 120 show by how much it is the larger. The cotyledons are of an orange-claret colour. They become horizontal in the seedling: and a pair of leaves follow them.

Twice cotyledons, folded into an S, were found.

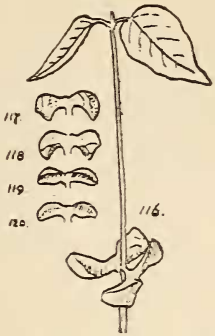


Figure 116, a seedling of *Hopea Curtisii*, $\frac{2}{3}$ nat. size; figure 117, its outer cotyledon from outside; figure 118, from inside; figure 119, the placentar cotyledon from the side towards the outer cotyledon: and figure 120, from the other side, all ½ nat. size.

The attention of the reader may be called to faint grooves on the surface of the cotyledons, which are due to raised lines in the fruit wall. The splitting of the fruit wall as the seed germinates is between these raised lines, or may rarely cross one or two of them, not being along any definite line of dehiscence, but apparently along any weak line upon which the cotyledons in their effort to flatten themselves press most. Therefore that the fruit of such Dipterocarps as *Vatica*, should usually free its seedling by splits along three lines is not to be assumed as connected with the trilocular nature of the ovary in the order, unless and until microscopic examination of successive stages in the development of the fruit has shown it to be so. *Retinodendron* frequently splits into two only; and in *Shorea sericea*, two and four splittings were found not infrequently.

Shorea.

Shorea in several species exhibits grooves on the embryo such as those to which attention has just been called under *Hopea Curtisii*. They are particularly obvious in *Shorea costata*, King.

Figure 121 is its embryo with the radicle remote from the observer, and 122 is the same from the side with the placentar cotyledon towards the observer. As in *Hopea Curtisii* the outer cotyledon is the larger and shuts the placentar cotyledon out from the apex of the ovary.

Figure 121, the embryo of *Shorea costata* with the radicle away from the observe; figure 122, the same with the placentar cotyledon towards the observe, ½ nat, size.

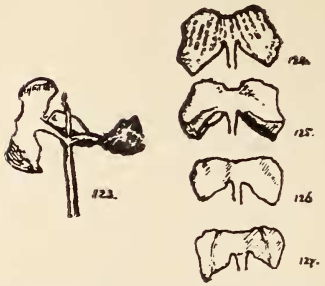
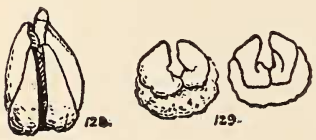


Figure 123, young seedling of *Shorea castata* ; and figure 124, its outer cotyledon from outside, figure 125, from inside ; figure 126, the placentar cotyledon from the side towards the outer cotyledon ; and figure 126, the same from the other side, ½ nat. size.

Shorea materialis, Ridley, has an embryo with the cotyledons similarly proportioned towards each other, but my material was not quite mature, the embryos lying in a little unabsorbed albumen, so that their surface was not pressing upon the ovary wall.

The embryo of *Shorea gratissima,* Dyer, differs in several points; first of all it is longer than those of *Shorea costata* and *S. materialis;* then it is threaded through by a particularly large placenta; and thirdly the placentar cotyledon exhibits a peculiar folding along it. The placentar cotyledon does not attain the apex of the fruit cavity, but approaches it more nearly that in *S. costata* and *S. materialis.* Both cotyledons are grooved by ridges of the fruit-wall. A pair of leaves follows the cotyledons, and these, as well as those which follow, possess a peculiar blue green tint which has not been seen in any other species of the order.

There was no chlorophyll in the cotyledons at seed-fall: all other Shoreas examined possess it.



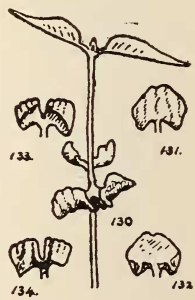


Figure 128, embryo of *Shorea gratissima* with the placentar cotyledon towards the observer; figure 129, the same with the radicle away from the observer, and also in section through the bodies of the cotyledons above the plumule, showing the folds of the placentar cotyledon. All slightly enlarged.

Figure 130, a seedling with its first leaves ; figure 131, the outer cotyledon from the outside; figure 132, from the inside; figure 133, the placentar cotyledon from the side towards the outer cotyledon ; and figure 134, from the other side. All ½ nat. size.

Shorea pauciflora, Dyer, has a large fruit very like that of *S. costata,* but a trifle greater in length. The embryo seen with the radicle away from the observer is drawn in figure 135. The seedling produced is relatively large, so that with practise it can be detected by eye among the seedlings of other species. The cotyledons are as figured below (figures 136, 137, 138 and 139). The groove in which the placenta lies is not quite so narrow as in some other Shoreas.

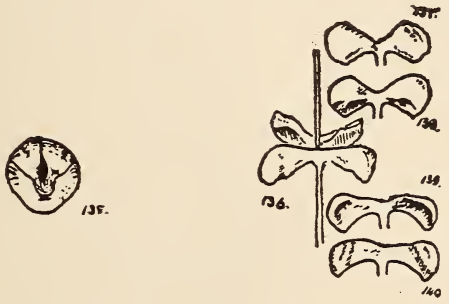


Figure 135, embryo of *Shorea pauciflora* with the radicle away from the observer; figure 136, the cotyledons of *Shorea pauciflora*; figure 137, the outer cotyledon from the outside; figure 138, from the inside; figure 139, the placentar cotyledon from the side toward the outer cotyledon; figure 140, from the other side. Figure 136-140 ½ nat. size.

Shorea pauciflora has a downwardly directed urceolate flower, which seems characteristic.

Figure 141, a flower of *Shorea pauciflora* in face view and in vertica section, × 2.

Shorea utilis, King, is the subject of figures 142 to 148. The fruit is rather short (figure 143) and the embryo has its placentar cotyledon only just shut off from the apex of the fruit cavity.

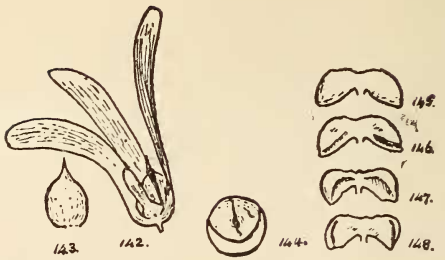


Figure 142, the fruit of *Shorea utilis* with its wings; ½ nat. size; and figure 143 without; figure 144, the embryo with the radicle away from the observer; figure 145, the outer cotyledon from the outside; figure 146, from the inside; figure 147, the placentar cotyledon from the side towards the outer; and figure 148, from the other side. Figures 145-148, nat. size.

Shorea macroptera, Dyer. drawings of which follow, has the cotyledons slightly unequal.

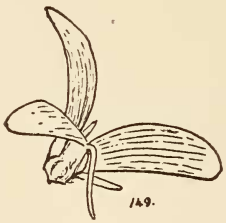


Figure 149, germinating fruit of *Shorea macroptera*, ¼ nat. size.

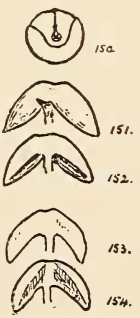


Figure 150, a diagram of the embryo of *Shorea macroptera* as seen with the radicle remote from the observer showing how much of the circumference is occupied by the outer cotyledon; figure 151, the outer cotyledon seen from outside: figure 152, from inside; figure 153, the placentar cotyledon seen from the side towards the outer cotyledon; and figure 154, from the other side figure 151—154 ½ nat. size.

In this Journal No. 76, 1917, p. 166, attention was called to the finding in Singapore of seedlings with three cotyledons: three similar plants were found in Penang in 1918.

Shorea parvifolia, Dyer, has a subglobose capsule: and the embryo has unequal cotyledons, the outer by a little shutting out the placentar cotyledon from the apex of the fruit cavity. The seedling is small in comparison with that of other Shoreas.

Twin seeds were found.

Shorea scutulata, King, has a capsule slightly elongated, the outer cotyledon just shutting the placentar cotyledon out from the apex of the fruit-cavity: these cotyledons appear almost equal after germination.

Figure 155, seedling of *Shorea sentilata*, ½ nat. size.

Illustrations of *Shorea Curtisii*, King, follow. It is a species very common on the hills of Penang and rather variable in the shape and size of the fruit as well as in the length and breadth of the calyx-wings, so much so that ultimately several varieties are likely to be distinguished, the fruits of two of which are figured here (figures 165 and 170). Both are represented among the specimens cited by Sir George King in describing the species, so that both are his *Shorea Curtisii*.

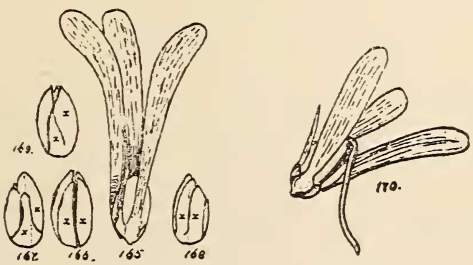


Figure 165, fruit of a variety of *Shorea Curtisii*, with long wings; figure 166, normal embryo of the same with the placentar cotyledon, x-x, towards the observer; figures 167 and 168, abnormal embryos in which the placenta (dotted line) did not occupy the cleft between the lobes of the placentar cotyledon in a normal way; figure 169, an abnormal embryo with one lobe of the placentar cotyledon small. All ½ nat. size.

Figures 170, fruit of a second variety of *Shorea Curtisii* more common in Penang island than the first, ½ nat. size.

The normal cotyledons are not markedly unequal: the outer occupies rather more than one half of the circumference of the embryo as seen with the radicle away from the observer, and just shuts out the placentar cotyledon from the apex of the fruit: but occasionally it may much outgrow it. For cases of nearly equal cotyledons see figures 171-179.

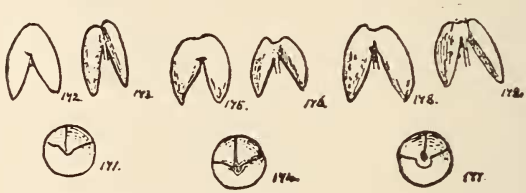
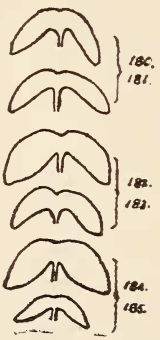


Figure 171, an embryo of the variety of *Shorea Curtisii* figured above as 165, viewed with the radicle away from the observer; figure 172, the outer cotyledon from outside; and figure 173, the inner cotyledon from the face away from the outer cotyledon; figure 174, the naked embryo of the variety drawn above as figure 170, viewed with the radicle away from the observer: and figure 175, the outer cotyledon of the same from outside; and figure 176, the inner cotyledon from the side away from the outer cotyledon; figure 177, a naked embryo of the same variety as figure 170 viewed with the radicle away from the observer; and figure 178, the outer cotyledon from outside; and figure 179, the inner cotyledon from the side away from the outer cotyledon. All ½ nat. size.



Figures 180 to 185, outlines of the cotyledons of three seedlings of *Shorea Curtisii* showing varying degrees of disparity between the cotyledons, the outer cotyledon is the upper of each pair. All ½ nat. size.

Four cases are shown in figures 167 and 168 in which the placentar cotyledon failed to lie against the placenta in a normal way but had, as it were, got across it, so that the placenta had left a shallow impression upon the face of the cotyledon,—a slight groove like the grooves seen in *Shorea costata,* and the result of pressure. These abnormalities were not accompanied by the presence of any twin seed. Again an abnormality is figured in figure 169 in which the lobes of the cotyledons had grown unequally.

Perhaps because I have found so many more thousands of its seeds and seedlings on the hills of Penang than of other Shoreas, I have found such abnormalities in it only.

The next Shorea to be illustrated is *Shorea sericea,* Dyer. Like *Shorea rigida,* Brandis, from which as a species it is doubtfully distinct, it has nearly equal cotyledons, the outer only just the larger, of the same shape as those of *Shorea rigida* (vide this *Journal* No. 76, 1917, p. 164). One case of a seedling with three nearly equal cotyledons was found in Penang.

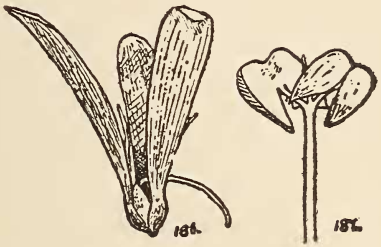


Figure 186, the fruit of *Shorea sericea* germinating, $\frac{2}{3}$ nat. size ; figure 187 a seedling with its cotyledons in the position that they assume, slightly reduced

Figure 188, an embryo of *Shorea sericea* seen with the radicle away from the observer ; figure 189, the outer cotyledon seen from the outer side ; and figure 190, the inner cotyledon seen from the side away from the outer cotyledon. Figures 189 and 190, $\frac{1}{2}$ nat. size.

Shorea sericea flowered in 1918 in Penang a couple of months later than the other Shoreas associated with it.

The last of the seedling Shoreas to be illustrated here is *S. bracteolata,* Dyer. Other species illustrated above have thick cotyledons: they have been arranged into a series commencing with those having cotyledons markedly unequal, and ending with those having cotyledons equal. *S. bracteolata* does not fit into the series, but like *S. leprosula* has flat cotyledons. Attention was called to them in this Journal No. 76, 1917, p. 164, where the cotyledons of *S. leprosula* were described. Unlike *S. leprosula* it has a large flower directed earthwards.

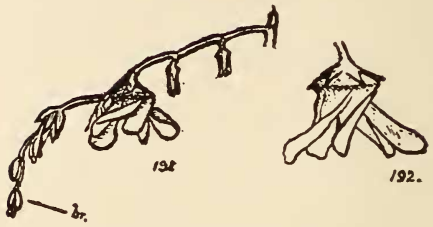


Figure 191, a branch of the compound raceme of *Shorea bracteolata* showing the natural position of the flower: br. = bracts, $\frac{2}{3}$ nat. size; figure 192, a flower of *Shorea bracteolata*. nat. size.

The young plant is drawn in figure 193 and the normal condition of the cotyledons in 194, 195, 196 and 197.

An abnormal seed was found with the placentar cotyledon much larger than the outer (figures 198, 199, 200, and 201).

The leaves of the pair which follow the cotyledons are more triangular than the leaves of the mature tree. Figure 12 on p. 165 of this Journal No. 76, 1917, suggests this, but is not good for its purpose.

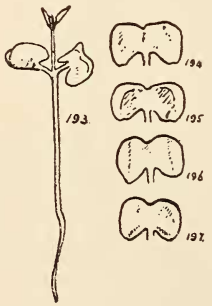
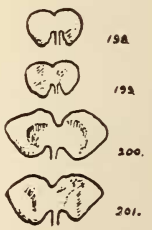
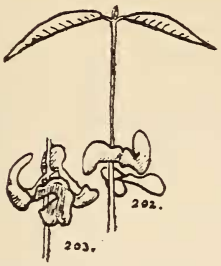


Figure 193, a seedling of *Shorea bracteolata*, showing the position taken by the cotyledons; figure 194, the outer cotyledon from the outside; figure 195; the same from the inner side; ffgure 196, the placentar cotyledon from the side toward the outer cotyledon; and figure 197, thu same from the other side, ½ nat. size.



Figures 198 to 201, the cotyledon of an abnormal seed of *Shorea bracteolata*; figure 198, the outer cotyledon from tho outside; figure 199, the same from inside; figure 200, the placentar cotyledon from the side toward the outer cotyledon; and figure 201, the same from thc other side, Nat. size.



Figures 202 and 203, seedlings of *Shorea bracteolata* in which the cotyledons had been packed twisted into the shape of an S.

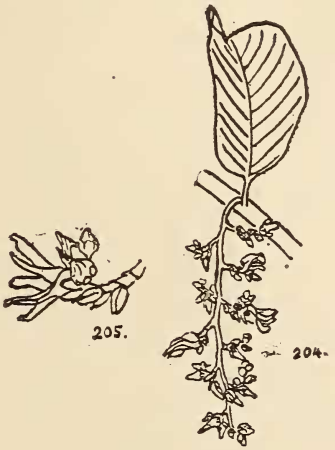


Figure 204, inflorescence of *Shorea lebrosula* to show the horizontal aspect of the flower, nat. size; figure 205, a branchlet slightly enlarged.

All the Shoreas here described except *S. bracteolata* develop red pigment in their seedlings. *S. macroptera* and *S. Curtisii* possess it also in the leaves which follow while they are quite young.

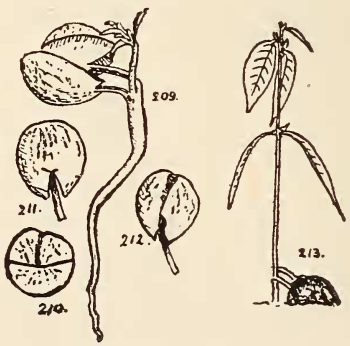
Pachynocarpus.

In many points the genus *Pachynocarpus* is unlike the other Dipterocarps here under discussion, and in none more so than that the fruits appear fitted for distribution by water. They, in *Pachynocarpus Wallichii*, are nearly globose, and the calyx is no larger than it was in the flower. The flower is drawn in figures 204 and 205 and the fruit just germinating in figure 206. Thirty-four fruits of the species were collected in the Botanic Garden, Singapore, in November, 1918 and kept in water with the intention of ascertaining how long they would float. The first to sink had floated only five days, the second ten days, but the rest floated various periods from ten to forty-six days; and the average of the thirty-four was twenty-two days. They germinated as they sank, the stalks of

the cotyledons pushing out a stout plantlet, which rather slowly produced its first foliage leaves. The cotyledons do not escape from the seed: for the purpose of drawing them they were freed as in figure 209: they are thick and approximately equal, dull yellow in colour, packed with starch, and without chlorophyll. The seedling does not look like that of a Dipterocarp. The fruit dehisces along three well defined lines obviously connected with the tri-locular nature of the ovary. The placenta leaves but a shallow impression down the placentar cotyledon.

Figure 206, the flower of *Pachynocarpus Wallichii* from the side; figure 207, the same in section.

Figure 208, the germinating fruit of *Pachynocarpus Wallichii*, the radicle just extruded.



Fgure 209, a seedling of *Pachynocarpus Wallichii*, the fruit wall has beon removed, on doing which the cotyledons part a little in consequene of stresses in their petioles, ½ nat. size; figure 210, the embryo of *Pachynocarpus Wallichii* with the radicle away from the observer; figure 211, the cotyledon which is the outer in *Dipterocarpus* from the outside; figure 212, the placentar cotyledon with the side away from the other cotyledon toward the observer.